A Q U A P H Y T E

UNIVERSITY OF FLORIDA
CENTER FOR AQUATIC PLANTS
INSTITUTE OF FOOD AND AGRICULTURAL SCIENCES

With Support From
The Florida Department of Natural Resources, Bureau of Aquatic Plant Management
The U.S. Army Corps of Engineers, Waterways Experiment Station,
Aquatic Plant Control Research Program

Volume 12 Number 1 Spring 1992 **GAINESVILLE, FLORIDA** **ISSN 0893-7702**

Exotic Fern A Threat to Wetlands

Yet another potentially serious exotic weed is spreading throughout the southeastern U.S. Although cultivated for its attractive soft green foliage, the **Japanese Climbing Fern** (*Lygodium japonicum*) is beginning to be seen as a threat to the native vegetation of shady wetlands such as floodplain forests.

The threat may be most real in South Florida, where year-round temperatures enable the naturalized plant to keep on growing, and growing, and growing...

The resulting tangled canopy of six-to-*one hundred*-foot-long fronds of the fern can be so dense that plants underneath them die for lack of sunlight.

This Asian exotic first appeared in North Carolina around 1900, and since has become naturalized south to Florida and west to Texas.

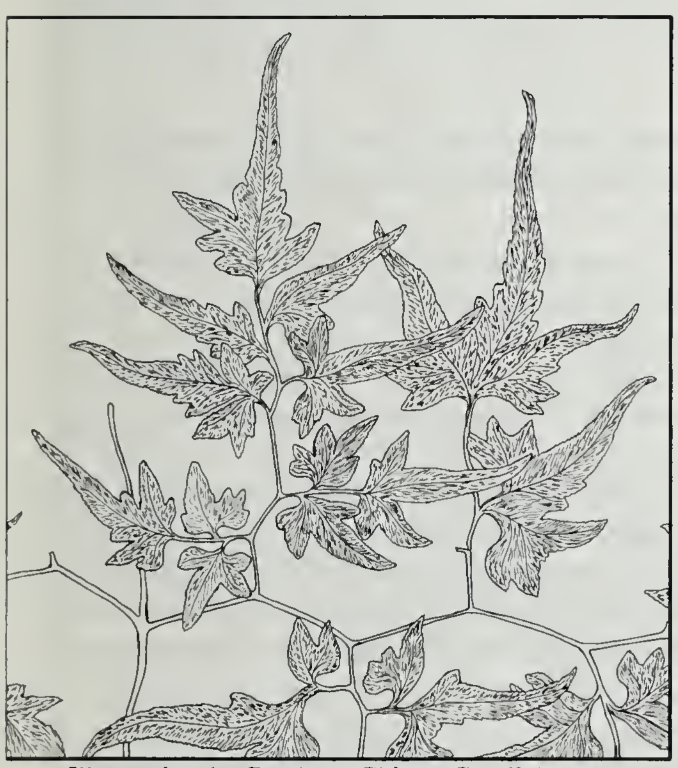

Illustration by Raphael Chiren Gottlieb

For an informative flyer, contact the APIRS office, address on page 16.

2 x CO_2 = X Aquatic Plants

Since the beginning of the industrial age, atmospheric carbon dioxide (CO_2) has increased by 25% to the current level of about 350 parts per million. Fuel combustion and deforestation are considered major contributors to this increase. Experts believe that CO_2 concentrations around the world will double by the end of the 21st century.

What will be the effects of increased carbon dioxide on plants? Will there be a "CO_2 fertilization effect" that makes plants grow larger and faster? Will increased CO_2 be a boon to agriculture? What will be the effects on unmanaged wild plants? Will certain plants make better use of the elevated CO_2 and replace other plants, thereby reducing biological diversity? How will animals react to the plant changes? Scientists are working to find answers to these questions, answers that might be used in predictive models that may help us plan for the coming changes.

The positive effects of increased CO_2 on plant growth have been known for the past two centuries. Photosynthesis is one of the most studied of natural phenomena. However, until the "greenhouse effect" controversy, little work had been devoted to the effects of elevated levels of CO_2 on plants. Now, many researchers are studying the effects of increased CO_2 on many parts of the environment, including aquatic plants.

One of the first major calls for work on elevated CO_2 and aquatic plants came in 1983 when R.G. Wetzel, J.B. Grace and a panel of other scientists reviewed the research and found it wanting. They recommended that programs be started to study the long-term effects of CO_2 enrichment; the mechanisms of C and O_2 supply and plant adaptations; nitrogen fixation; nutrient sequestering; noxious byproducts; and litter production and how it affects growth and plant population change.

A search of the APIRS aquatic plant database reveals that during the past ten years, a few dozen studies have been published about aquatic plant responses to elevated CO_2 levels. Listed below are some of them. (Many more studies about effects of elevated CO_2 on terrestrial plants have been published.) In addition, more than 500 studies are in the APIRS database about how aquatic plants actually use carbon sources (such as carbon dioxide) for photosynthesis.

Aquatic Plant Research

The following researchers have found a variety of responses of aquatic plants to elevated CO_2 levels in the air and water. It appears that, generally, a doubling of atmospheric CO_2 concentrations increases plant growth by approximately 30%. However, elevated CO_2 effects depend on a plant's photosynthetic pathway as well as on the interactive effects of light intensity, temperature, pH, oxygen concentration, nutrient availability, salinity and possibly other factors such as starch accumulation and plant shoot architecture. In the words of one researcher (Idso), "predicting the ultimate biospheric consequences of a doubling of the earth's atmospheric CO_2 concentration may prove to be much more complex than originally anticipated."

[See CO_2 on page 12]

Study This!

AQUATIC MACROPHYTES AND THEIR RELATION TO THE LIMNOLOGY OF FLORIDA LAKES by D.E. Canfield and M.V. Hoyer. 1992. 609 pages.

"Lakes in Florida are important resources and they often must be managed for a variety of purposes including flood control, water supply, fishing and general recreation. Lake usage, however, is a match between people's desires and the lake's capacity to satisfy these desires. Lake problems are defined in terms of the limits on desired uses. Many limitations can be prevented or corrected with proper lake management, but desired uses need to be clearly defined, limitations on the uses identified, and the causes understood."

The purpose of this study was to determine how aquatic plant management plans may affect water quality, fish populations and bird populations in Florida lakes. The five year study included 60 lakes of varying trophic states, size, depth and aquatic plant coverage.

Among the significant findings are:

- consistent with previous studies, total fish biomass increased as the lakes increased in trophic status; fish ranged from 6 kg/ha (5 pounds/acre) in an oligotrophic lake to 675 kg/ha (602 pounds/acre) in a hypereutrophic lake.
- fish populations are likely to be depressed when there are either too many or too few aquatic macrophytes.
- harvestable fish and sportfish populations in lakes having no aquatic macrophytes due to grass carp, showed no consistent trends. Thus long-term loss of macrophytes will not necessarily decrease the lake's fish populations.
- as in fish populations, bird abundance increased as the lake's trophic state increased.
- in a turbid nutrient-rich lake with no aquatic plant coverage, the cover must be raised to 30% to 50% before significant improvements in water clarity (chlorophyll *a* concentrations) will be observable. Conversely, significantly *reducing* macrophyte coverage of a lake, for example from 60% to 20% or from 40% to 0%, will cause significant and observable water quality (water clarity) changes.
- leaving a small fringe of vegetation around a lake for the purpose of water quality improvement will have little or no effect on the lake's trophic state values (total phosphorus, total nitrogen, chlorophyll *a*, algal levels and Secchi transparency).

With these findings in mind, the scientists suggest that a moderate amount of aquatic macrophytes would be beneficial to most Florida lakes. To preclude fisheries problems, a reasonable management objective for most Florida lakes may be a macrophyte coverage of at least 15% including emergent, floating-leaved and submersed vegetation.

Objectives such as this require a long-term commitment to some level of aquatic plant management. The authors also recommend "maintenance control" of non-native species such as hydrilla and water hyacinths so as not to allow these plants to completely take over lakes and replace native species.

The authors complete the study by recommending future research thrusts: develop better biocontrol techniques; develop species-specific aquatic plant management methods; find a method to remove grass carp after their work is done; find the environmental ranges of individual aquatic plant species; ascertain the relationships between water chemistry, lake morphology and macrophyte species composition; identify the management objectives for each lake; and develop better education for the general public about how lakes function, the values of macrophytes, and the risks and benefits of the various management methods.

A limited number of copies of this report are available from M.V. Hoyer, Department of Fisheries and Aquaculture, Center for Aquatic Plants, University of Florida, 7922 N.W. 71st Street, Gainesville, FL 32606, (904) 392-9617.

AT THE CENTER

FISH AND HERBICIDES

How do largemouth bass react when the waterhyacinths they live around are sprayed with the herbicide 2,4-D? New graduate student Marvin Boyer hopes to address this controversy in aquatic plant management while gaining his master's degree. Working under Dr. Chuck Cichra (Fisheries and Aquaculture) and Dr. Bill Haller, Boyer comes to Gainesville from the University of Wisconsin, Stevens Point.

Will largemouth bass abandon a home range when their vegetation cover drops out or will they stay to take advantage of prey species left without host plants? What will they do if oxygen levels drop as plants decompose? Does a repellant component in the herbicide induce them to move or do airboats simply get on their nerves? Does spraying herbicides affect their behavior during the spawning season, affecting reproduction?

Tank studies will be used to determine if feeding habits are affected by the presence of 2,4-D in the water. In field studies, Boyer will capture and radio-tag largemouth bass this fall when cooler water temperatures will lessen the dangers of mortality to the fish. They will be released and monitored throughout the winter to determine their home ranges. After this phase is complete, experiments will monitor the reactions of the bass to herbicide spraying and vegetation loss. Possible study sites include Lake Rousseau and Bivens Arm in Florida.

Research Review Review

The Center's annual aquatic plant research review on March 31 once again drew dozens of scientists of all disciplines to share their latest data.

Among them were USDA's Dr. Ted Center who reported on hydrilla biocontrol efforts in Florida. According to Center, several ponds full of hydrilla have "dropped out" within months of introducing the aquatic fly *Hydrellia pakistanae* (right). Center says his group "can't really say the insects did it" yet, but the coincidences are piling up, and so are their fly establishment and monitoring efforts.

In another talk, Dr. D.F. Martin (Univ. South Florida) reported having isolated a possible fungus (a "white filamentous material") that may be preventing hydrilla from growing in a certain lake near Tampa. He hypothesizes that whatever is stifling the hydrilla is somehow connected to whatever decomposed the tons of cypress logging residues that were dumped into the same lake decades ago.

In their hydrilla physiology research, Drs. Mark Rattray and George Bowes (Univ. Florida) reported that for the first time, AHAS has been extracted from hydrilla. AHAS (acetohydroxy acid synthase) is a key enzyme in the biosynthesis of amino acids essential for growth. Their studies with "Mariner" herbicide indicate that the herbicide's mode of action against hydrilla is to quickly and greatly inhibit AHAS activity.

Other researchers presented talks about aquatic plant clone culturing, surveys of invertebrates on aquatic plants, aquatic herbicide research, grass carp studies and the economics of aquatic plant management.

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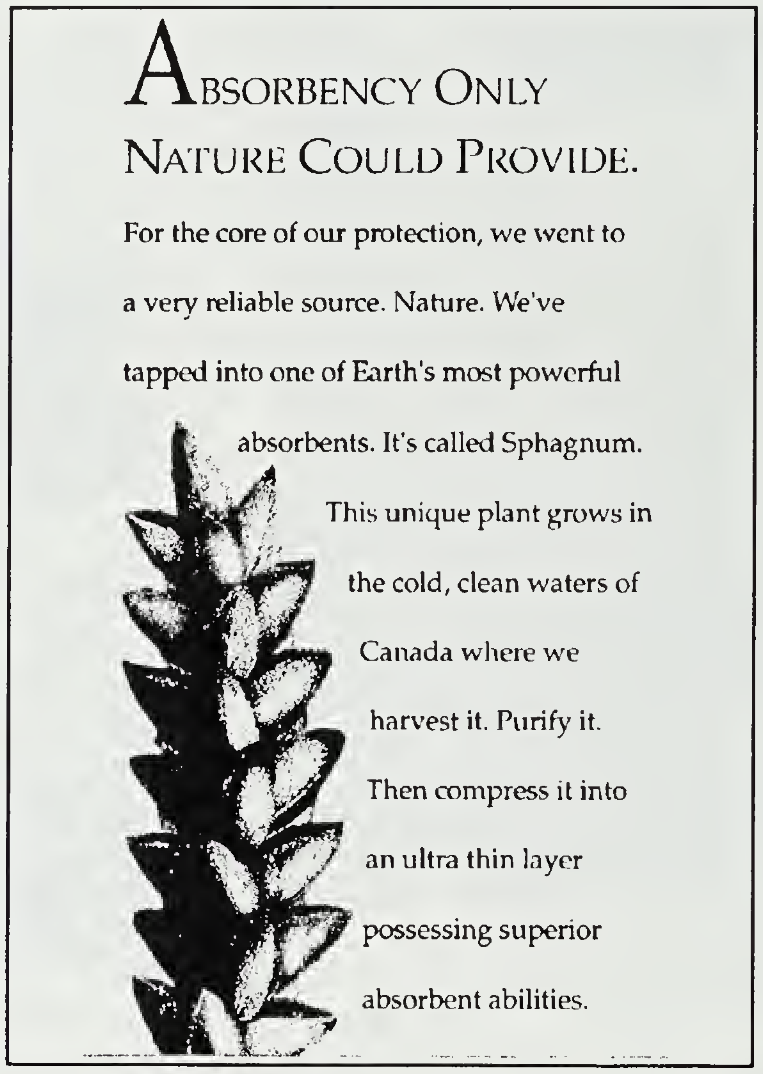
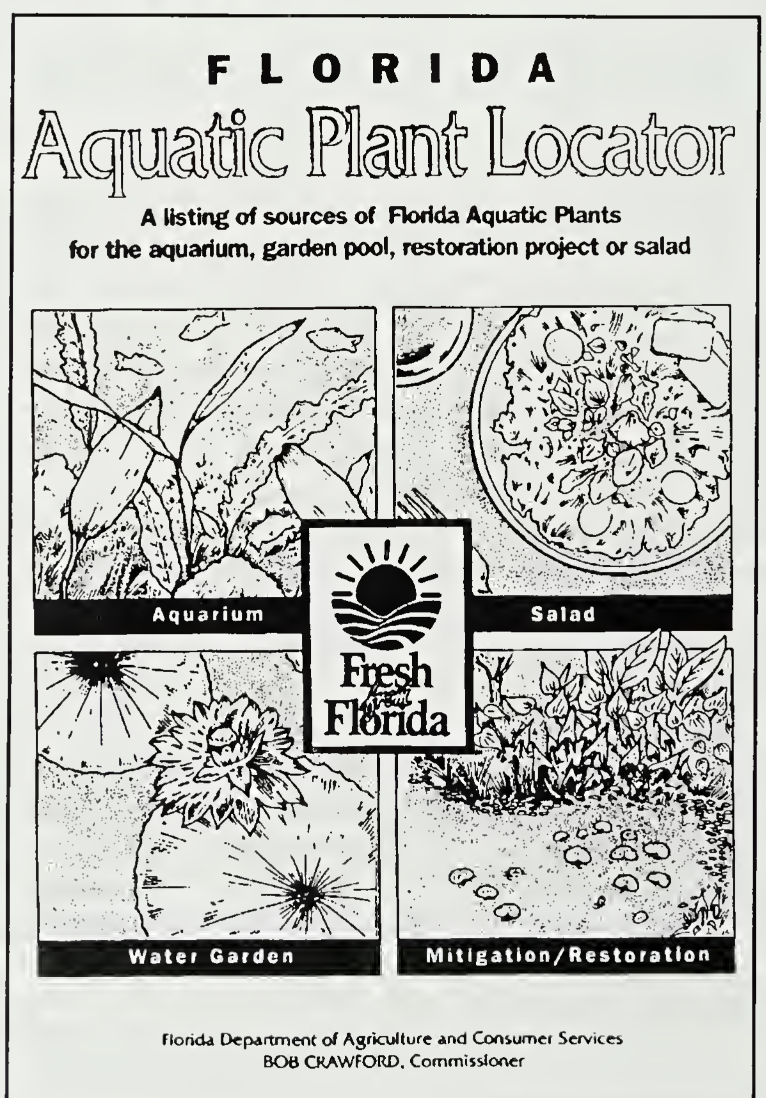
Dr. Joseph Joyce, Director

Aquatic Plant Growers - Information Update

Those ubiquitous aquatic plants. If you are an aquatic plant manager, researcher, cultivator, extension agent or information specialist, you probably feel like you work in a rather remote field. But wherever you go, you see them in one form or another. *Nelumbo* seed pods in dried flower arrangements, talcum powders from wet-meadow plants, vitamin supplements from dried *Lyngbya,* lip balm from *Melaleuca alterniflora* oil, *Sphagnum* in 'feminine products', candles in the shape of *Nymphaea, Nymphaea* Eau de Parfum (at $30.00 per bottle, according to the ad "a woman sprays it only where she wants to be kissed. . ."), *Ranunculus* on tea towels, *Trapa* in Asian food markets, *Typha* everywhere, and of course, aquariums and ornamental ponds.



According to the Florida Department of Agriculture and Consumer Services (FDACS), Florida's aquatic plant industry sold $7 million worth of aquatic plants in 1989. To assist people in this industry, FDACS recently published the *Florida Aquatic Plant Locator.* The book lists retail and wholesale suppliers of plants for aquariums, ponds, food, and wetland restoration and mitigation. The book includes listings of exporters, installation and maintenance services, landscape architects, production and technical information, trade associations and regulatory agencies.



The **Florida Aquatic Plant Locator** is $3.50, payable to FDACS. FDACS, Aquaculture Program, Room 425, Mayo Building, Tallahassee, FL 32399-0800, (904) 488-4033.

Mags and Orgs

The Aquatic Gardener is the journal of the **Aquatic Gardeners Association,** whose stated purpose is to disseminate information about, to study and improve culture techniques for, and to increase interest in, aquatic plants. Mostly comprised of articles from members, the journal focuses on practical information about growing aquarium plants for the hobbyist. The Technical Advisory Committee of the association offers a question and answer section in the bi-monthly journal.

The Aquatic Gardeners Association, 83 Cathcart Street, London, Ontario, N6C 3L9, CANADA. Membership, $15.00 yearly in N. America, $28.00 overseas.

The National Pond Society is "dedicated to helping people to be successful pond keepers at home, in community groups and in institutions because we believe 'pondering' adds joy to living while improving the environment and encouraging an appreciation of the earth."

Pondscapes is the society's monthly magazine, and is written "for and by pond keepers". It is packed with information. A recent issue contained articles about pond fish, dissolved oxygen, building waterfalls, growing water lilies, drying water lilies, and tips for planning and building water gardens. The December issue contains a national directory of suppliers of pond products and services and lists volunteers in over twenty-five states who are willing to field questions on water gardening.

Upcoming events of the Society include the Atlanta Tour of Ponds and the American Pond and Garden Expo in June 1992. The group has many interesting ideas and projects, such as starting a pond keepers youth group, wildlife habitat pond projects for grammar schools, and volunteering labor for special groups such as the Atlanta Zoo and the Jewish Nursing Home's therapeutic gardening service.

The National Pond Society, P.O. Box 449, Acworth, GA 30101, (404) 975-0277. Membership, $18.00 yearly domestic, $36.00 foreign and commercial.

BOOKS/REPORTS

ATTRIBUTES OF WISCONSIN LAKE PLANTS by S.A. Nichols and J.G. Vennie, Wisconsin Geological and Natural History Survey. 1991. 19 pages.
(Order from University of Wisconsin - Extension, Geological and Natural History Survey, Map and Publications Office, 3817 Mineral Point Road, Madison, Wisconsin 53705, 608/263-7389. Information Circular 73. $3.00 plus $1.50 postage.)

Published for aquatic plant managers, this deceptively thin circular includes more practical information about aquatic plants than many publications 10 times its size. It is meant to help managers "to know which species are desirable and how to encourage them as well as which species are likely to be nuisances and how to discourage them."

This collection of five simple "attribute tables" of 149 aquatic plants lists the plants, their habitat preference, wildlife and environmental value, propagation method, and herbicide susceptibility.

The book is very easy to use and understand: managers, students and other users will be surprised by how much they can learn from simple tables.

BIOLOGICAL CONTROL OF WEEDS - A HANDBOOK FOR PRACTITIONERS AND STUDENTS by K.L.S. Harley and I.W. Forno, CSIRO, Australia. 1992. 88 pages.
(Order from Butterworth-Heinemann, 271-273 Lane Cove Road, P.O. Box 345, North Ryde, N.S.W. 2113, AUSTRALIA. Aud$39.95.)

Written by two of the foremost experts in the subject, this book is a concise treatment of the background and procedures involved in the use of the biological method of controlling weeds. It would be useful to anyone interested in the subject, from students to experienced scientists.

The book discusses all aspects of a biological control project including the selection of the target weed; finding effective control agents; ensuring that the agents are host-specific and free of diseases and parasites; and the rearing, distribution and monitoring of biological agents. It also contains chapters on the history of classical biological control. Also included is an appendix outlining the design and operation of insect reception and quarantine facilities.

CONSERVATION GUIDELINES FOR ASSESSING THE POTENTIAL IMPACTS OF WASTEWATER DISCHARGES TO WETLANDS by J.G. Cooke, Water Quality Centre, DSIR, New Zealand. 1991. 49 pages.
(Order from Water Quality Centre, DSIR Division of Water Sciences, P.O. Box 11-115, Hamilton, NEW ZEALAND.)

According to the author, the concept of using New Zealand wetlands for disposal of wastewaters has become increasingly popular for two reasons: 1) "it is extremely cost-effective" and 2) "...there is increasing understanding of the Maori perspective on waste disposal, which opposes direct discharge of sewage into natural waters because it is an affront to its wairua and therefore affects the mana of those who use it."

This report is for conservation officers who are responsible for evaluating applications to discharge wastewater into wetlands. It includes a review of the ecological impacts of wastewaters on wetlands and presents guidelines for assessing waste discharge proposals.

THE ECOLOGY OF TROPICAL LAKES AND RIVERS by A.I. Payne, Coventry Polytechnic. 1986. 301 pages.
(Order from John Wiley & Sons, Inc, 1 Wiley Drive, Somerset, New Jersey 08875-1272, 201/469-4400. $84.95 cloth.)

This "self-contained textbook for students from tropical countries" explains all important concepts of aquatic ecology in the tropics. The book includes chapters about river and lake environments including water chemistry, drainage basins and morphometry, hydrology, and stratification. Also included are chapters about the community structures and dynamics of plankton, benthic animals, and macrophytes, including text on primary productivity, nutrient cycling and secondary production. Seasons, phenology, and animal periodicity are discussed in one chapter; diversity and evolution are discussed in another. The final chapter discusses aquaculture and fisheries management.

LIGHT CLIMATE AND ITS IMPACT ON POTAMOGETON PECTINATUS L. IN A SHALLOW EUTROPHIC LAKE by G.M. van Dijk. 1991. 125 pages.

The purpose of this book is to examine the effects of eutrophication and light on algal and vascular plant growth, abundance and succession. One general hypothesis could be described: increased nutrients in a lake cause algal populations to increase, thereby reducing light to submersed plants. The submersed plants die off, thus making even more nutrients available to algal populations.

The final part of this book is a discussion of lake restoration projects in The Netherlands. It includes an assessment of the potential of biomanipulation (using fish, sediment-management and macrophyte re-establishment) as a method to restore eutrophic lakes. The author concludes that water quality managers should pay more attention to submersed vegetation, which has positive and negative impacts on the functioning of shallow aquatic ecosystems.

ISOZYMES IN WATER PLANTS, Opera Botanica Belgica 4, edited by L. Triest. 1991. 264 pages.
(Order from Dr. R. Clarysse, National Botanic Garden of Belgium, Domein van Bouchout, B-1860 Meise, BELGIUM. 1600 BEF, plus 300 BEF for foreign checks.)

An "isozyme" (=isoenzyme) is a molecular form of an enzyme. Electrophoretic analysis of isozymes enable researchers to identify species, clones, races and populations. Among other benefits, such analysis of aquatic plants ultimately helps in working out appropriate control and management programs, especially for plants deemed "weeds".

This book is a review of the electrophoretic studies in aquatic macrophytes and algae. It includes information on the molecular systematics and biogeography of *Alisma, Baldellia, Hydrilla, Lagarosiphon, Potamogeton, Ruppia, Zannichellia, Najas* and the seagrasses.

FROM THE DATABASE

Here is a sampling of the research articles, books and reports which have been entered into the aquatic plant database since November, 1991.

The database has more than 33,000 items. To receive free bibliographies on specific plants and/or subjects, contact APIRS at the address shown on the mail label on page 16.

To obtain articles, contact your nearest state or university library.

Agusti, S.; Duarte, C.M.; Canfield, D.E.
Phytoplankton abundance in Florida lakes: evidence for the frequent lack of nutrient limitation.
LIMNOL. OCEANOGR. 35(1):181-188, 1990.

Alimi, T.; Akinyemiju, O.A.
Effects of waterhyacinth on water transportation in Nigeria.
J. AQUATIC PLANT MGMT. 29:109-112, 1991.

Anderson, L.W.J.; Perry, S.
Effects of triclopyr on *Ludwigia peploides* and *Myriophyllum spicatum*.
IN: ANNUAL REPORT - 1990: AQUATIC WEED CONTROL INVESTIGATIONS, ANDERSON, L.W.J., RYAN, F.J. AND SPENCER, D.F., EDS., USDA, AGRIC. RES. SERV., BOT. DEPT., UNIV. OF CALIF., DAVIS, PP. 19-21, 1990.

Appenroth, K.J.; Hertel, W.; Augsten, H.
Photophysiology of turion germination in *Spirodela polyrhiza* (L.) Schleiden. The cause of germination inhibition by overcrowding.
BIOLOGIA PLANTARUM 32(6):420-428, 1990.

Archibold, O.W.; Reed, W.B.
Airboat design and operational losses of a wild rice harvester.
CAN. AGRIC. ENGN. 32:69-74, 1990.

Armora, J.P.R.G.
Flora acuatica vascular (monocotiledoneas) del Estado de Chiapas.
MASTER'S THESIS, UNIV. NACIONAL AUTONOMA DE MEXICO, COYOACAN, 113 pp., 1991. (In Spanish)

Austin, A.P.; Harris, G.E.; Lucey, W.P.
Impact of an organophosphate herbicide (glyphosate) on periphyton communities developed in experimental streams.
BULL. ENVIRON. CONTAM. TOXICOL. 47:29-35, 1991.

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The carboxylase activity of Rubisco and the photosynthetic performance in aquatic plants.
OECOLOGIA 87:429-434, 1991.

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Changes in the abundance of two atherinid species after aquatic vegetation removal.
TRANS. AMER. FISH. SOC. 120:90-97, 1991.

Bowerman, L.; Goos, R.D.
Fungi associated with living leaves of *Nymphaea odorata*.
MYCOLOGIA 83(4):513-516, 1991.

Carter, V.; Rybicki, N.B.; Hammerschlag, R.
Effects of submersed macrophytes on dissolved oxygen, pH, and temperature under different conditions of wind, tide, and bed structure.
J. FRESHWATER ECOL. 6(2):121-133, 1991.

Cevallos-Ferriz, S.R.S.; Stuckey, R.A.; Pigg, K.B.
The Princeton chert: evidence for *in situ* aquatic plants.
REVIEW PALAEOBOT. PALYNOL. 70:173-185, 1991.

Chambers, P.A.; Hanson, J.M.; Prepas, E.E.
The effect of aquatic plant chemistry and morphology on feeding selectivity by the crayfish, *Orconectes virilis*.
FRESHWATER BIOL. 25:339-348, 1991.

Chand, T.; Lembi, C.A.
Gas chromatographic determination of flurprimidol in a submersed aquatic plant (*Myriophyllum spicatum*), soil, and water.
J. PLANT GROWTH REGUL. 10:73-78, 1991.

Chergui, H.; Pattee, E.
The processing of leaves of trees and aquatic macrophytes in the network of the River Rhone.
INT. REVUE GES. HYDROBIOL. 75(3):281-302, 1990.

Cooke, J.G.; Cooper, A.B.; Clunie, N.M.U.
Changes in the water, soil, and vegetation of a wetland after a decade of receiving a sewage effluent.
NEW ZEALAND J. ECOL. 14:37-47, 1990.

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Direct and indirect effects of wave attack on helophytes.
AQUATIC BOT. 41:333-352, 1991.

Counts, R.L.; Lee, P.F.
Germination and early seedling growth in some northern wild rice (*Zizania palustris*) populations differing in seed size.
CAN. J. BOT. 69:689-696, 1991.

Coutinho, M.E.
Ecologia populacional de *Eichhornia azurea* (Kth.) e sua participacao na dinamica da vegetacao aquatica da Lagoa do Infernao - SP.
DISSERTACAO DE MESTRADO, UNIVERSIDADE FEDERAL DE SAO CARLOS, UFSCAR, BRASIL. 145 PP. (In Portuguese)

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Acidification, metals and macrophytes.
ENVIRON. POLLUTION 71:171-203, 1991.

Daldorph, P.W.G.; Thomas, J.D.
The effect of nutrient enrichment on a freshwater community dominated by macrophytes and molluscs and its relevance to snail control.
J. APPL. ECOL. 28:685-702, 1991.

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Growth, decomposition, and nutrient retention of *Cladium jamaicense* Crantz and *Typha domingensis* Pers. in the Florida Everglades.
AQUATIC BOT. 40:203-224, 1991.

De Casabianca-Chassany, M.L.; Goma, G.
Treatment of paper industry effluents with *Eichhornia crassipes:* first results (Tartas factory, Landes).
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An experimental analysis of macrophyte growth forms as fish foraging habitat.
CAN. J. FISH. AQUAT. SCI. 48:123-131, 1991.

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Plant growth and productivity along complex gradients in a Pacific Northwest brackish intertidal marsh.
ESTUARIES 9(1):49-62, 1986.

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Studies of *Elodea nuttallii* grown under photorespiratory conditions. III. Quantitative cytological characteristics.
PLANT CELL ENVIRON. 14:167-173, 1991.

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The role of the plasma membrane proton pump in short-term pH regulation in the aquatic liverwort *Riccia fluitans* L.
J. EXPER. BOT. 42(238):645-652, 1991.

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The size and shape of traps of *Utricularia vulgaris* L.
FUNCTIONAL ECOL. 5:602-607, 1991.

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Samples of wet-marsh vegetation of Kyzylagash (Kazakhstan) Soviet Preserves.
J. AZERBAYJAN ACAD. SCI. 2:3-9, 1988. (In Russian)

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J. APPL. ECOL. 28:491-500, 1991.

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ENVIRON. SCI. TECHNOL. 25(5):924-929, 1991.

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Effects of underwater clipping of purple loosestrife in a southern Ontario wetland.
J. AQUATIC PLANT MGMT. 29:117-118, 1991.

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The significant role of *Chara hispida* - grown in water regime of a gravel pit lake at Senec.
ARCH. PROTISTENKD. 139:275-278, 1991.

Husband, B.C.; Barrett, S.C.H.
Colonization history and population genetic structure of *Eichhornia paniculata* in Jamaica.
HEREDITY 66:287-296, 1991.

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Wigeongrass (*Ruppia maritima* L.): a literature review.
U.S. FISH WILDL. SERV., FISH WILDL. RES. 10. 58 PP. 1991.

Kouki, J.
Small-scale distributional dynamics of the yellow water-lily and its herbivore *Galerucella nymphaeae* (Coleoptera: Chrysomelidae).
OECOLOGIA 88:48-54, 1991.

Kruger, L.; Kirst, G.O.
Field studies on the ecology of *Bolboschoenus maritimus* (L.) Palla (*Scirpus maritimus* L. S. L.).
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Associated weed flora and their susceptibility to herbicides in transplanted rice.
INDIAN J. AGRON. 36(1):113-116, 1991.

Lagarde, F.; Gauthier, M.
Heteranthera limosa (Sw.) Willd. (Pontederiaceae) en France.
BULL. SOC. BOT. FR. 138(3):239-240, 1991. (In French; English Summary)

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ESTUARIES 14(2):192-198, 1991.

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SCI. TOTAL ENVIRON. 103:215-227, 1991.

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AMER. J. BOT. 78(8):1070-1082, 1991.

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Nitrous oxide and dinitrogen emissions from *Panicum hemitomon* S. freshwater marsh soils following addition of N-15 labelled ammonium and nitrate.
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Linz, G.M.; Davis, J.E.; Engeman, R.M.; et al.
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HEAVY METALS ENVIRON. 2:172-175, 1991.

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AUST. J. MAR. FRESHWATER RES. 42:139-149, 1991.

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BIORESOURCE TECHNOL. 37:157-160, 1991.

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FLOATING AND FLOATING-LEAVED

1 Water hyacinth - *Eichhornia crassipes*
  Compare - Water hyacinth and Frog's-bit
2 Water lettuce - *Pistia stratiotes*
3 Frog's-bit - *Limnobium spongia*
4 Water fern - *Salvinia minima*
5 Mosquito fern - *Azolla caroliniana*
6 Small duckweed - *Lemna valdiviana*
  Compare - Small duckweed and Giant duckweed
7 Giant duckweed - *Spirodela polyrhiza*
8 Bog-mat - *Wolffiella gladiata*
9 Banana lily - *Nymphoides aquatica*
10 Water shield - *Brasenia schreberi*
11 Spatterdock - *Nuphar luteum*
12 Fragrant water lily - *Nymphaea odorata*
  Compare - Water lily and Spatterdock
13 Yellow water lily - *Nymphaea mexicana*
14 American lotus - *Nelumbo lutea*

EMERSED - PART I

1 Alligator weed - *Alternanthera philoxeroides*
2 American lotus - *Nelumbo lutea*
3 Arrow arum - *Peltandra virginica*
  Compare - Arrow arum, Common arrowhead, Wild taro
 Arrowheads - *Sagittaria* spp.
4 Coastal arrowhead - *Sagittaria graminea*
5 Common arrowhead - *Sagittaria latifolia*
6 Duck potato - *Sagittaria lancifolia*
7 Baby's-tears - *Micranthemum umbrosum*
8 Bacopa - *Bacopa* spp.
9 Blue flag - *Iris virginica*
10 Bur marigold - *Bidens mitis*
11 Buttonbush - *Cephalanthus occidentalis*
12 Cattails - *Typha* spp.
  Compare - Southern cattail and Common cattail
13 Elderberry - *Sambucus canadensis*
14 Fire flag - *Thalia geniculata*
15 Frog's-bit - *Limnobium spongia*
  Compare - Frog's-bit and Water hyacinth
16 Golden canna - *Canna flaccida*
17 Golden club - *Orontium aquaticum*
18 Hygrophila - *Hygrophila* spp.
  Compare - Lake hygrophila and East Indian hygrophila
19 Knotweeds - *Polygonum* spp.

EMERSED - PART II

20 Lizard's-tail - *Saururus cernuus*
21 Mermaid weed - *Proserpinaca pectinata*
22 Parrot feather - *Myriophyllum aquaticum*
23 Pickerelweed - *Pontederia cordata*
Compare - Pickerelweed and Common arrowhead
24 Red ludwigia - *Ludwigia repens*
25 Redroot - *Lachnanthes caroliniana*
26 St. John's-wort - *Hypericum* spp.
27 St. John's-wort - *Triadenum virginicum*
28 Spatterdock - *Nuphar luteum*
29 Swamp lily - *Crinum americanum*
Compare - Swamp lily and Spider lily
30 Swamp loosestrife - *Decodon verticillatus*
31 Water hemlock - *Cicuta mexicana*
32 Water horn fern - *Ceratopteris thalictroides*
33 Water pennyworts - *Hydrocotyle* spp.
34 Water primroses - *Ludwigia* spp.
35 Water spider orchid - *Habenaria repens*
36 Water spinach - *Ipomoea aquatica*
37 Wild taro - *Colocasia esculenta*

SUBMERSED - PART I

Arrowheads - *Sagittaria* spp.
1 Dwarf arrowhead - *Sagittaria subulata*
2 Strap-leaf sagittaria - *Sagittaria kurziana*
Compare - Strap-leaf sagittaria and Tape grass
3 Baby's-tears - *Micranthemum umbrosum*
4 Bacopa - *Bacopa* spp.
Bladderworts - *Utricularia* spp.
5 Bladderwort - *Utricularia foliosa*
6 Cone-spur bladderwort - *Utricularia gibba*
7 Purple bladderwort - *Utricularia purpurea*
8 Bog moss - *Mayaca fluviatilis*
Compare - Bog moss and Loose water milfoil
9 Common waterweed - *Egeria densa*
Compare - Common waterweed and Hydrilla
10 Coontail - *Ceratophyllum demersum*
11 East Indian Hygrophila - *Hygrophila polysperma*
12 Fanwort - *Cabomba caroliniana*
Compare - Fanwort and Limnophila
13 Hydrilla - Hydrilla verticillata

SUBMERSED - PART II

14 Limnophila - *Limnophila sessiliflora*
15 Muskgrass - *Chara* spp.
Pondweeds - *Potamogeton* spp.
16 Illinois pondweed - *Potamogeton illinoensis*
17 Sago pondweed - *Potamogeton pectinatus*
18 Clasped pondweed - *Potamogeton perfoliatus*
19 Southern naiad - *Najas guadalupensis*
20 Stonewort - *Nitella* spp.
Compare - Stonewort and Muskgrass
21 Tape grass - *Vallisneria americana*
Compare - Tape grass and Strap-leaf sagittaria
Water milfoils - *Myriophyllum* spp.
22 Eurasian water milfoil - *Myriophyllum spicatum*
23 Loose water milfoil - *Myriophyllum laxum*
24 Variable-leaf milfoil - *Myriophyllum heterophyllum*

GRASSES, SEDGES AND RUSHES - PART I

1 American cupscalegrass - *Sacciolepis striata*
Compare - American cupscalegrass and Maidencane
2 Bald-rush - *Psilocarya nitens*
3 Barnyardgrass - *Echinochloa* spp.
Beak-rushes - *Rhynchospora* spp.
4 Inundated beak-rush - *Rhynchospora inundata*
5 Small-headed beak-rush - *Rhynchospora microcephala*
6 Tracy's beak-rush - *Rhynchospora tracyi*
7 Bog buttons - *Lachnocaulon* spp.
Compare- Bog buttons and Hat-pins
Bog rushes - *Juncus* spp.
8 Soft rush - *Juncus effusus*
9 Needle rush - *Juncus roemerianus*
10 Shore rush - *Juncus marginatus*
Bulrushes - *Scirpus* spp.
11 Common three-square - *Scirpus pungens*
12 Soft-stem bulrush - *Scirpus validus*
13 Burhead sedge - *Scirpus cubensis*
Compare- Burhead sedge and Cyperus spp.
14 Salt-marsh bulrush - *Scirpus robustus*
15 Bur-reed - *Sparganium americanum*
16 Bushy beardgrass - *Andropogon glomeratus*
17 Common reed - *Phragmites australis*
Cordgrasses - *Spartina* spp.
18 Sand cordgrass - *Spartina bakeri*
19 Salt-marsh cordgrass - *Spartina alterniflora*
20 Giant cutgrass - *Zizaniopsis miliacea*
Compare- Giant cutgrass and Wild rice

GRASSES, SEDGES AND RUSHES - PART II

21 Hurricane-grass - *Fimbristylis spathacea*
22 Napiergrass - *Pennisetum purpureum*
Panicgrasses - *Panicum* spp.
23 Maidencane - *Panicum hemitomon*
24 Torpedograss - *Panicum repens*
Compare - Torpedograss and Maidencane
25 Guineagrass - *Panicum maximum*
26 Paragrass - *Brachiaria mutica*
27 Saw-grass - *Cladium jamaicense*
28 Southern cutgrass - *Leersia* spp.
Spikerushes - *Eleocharis* spp.
29 Road-grass - *Eleocharis baldwinii*
30 Club-rush - *Eleocharis cellulosa*
31 Giant spikerush - *Eleocharis interstincta*
32 Star-rush - *Dichromena* spp.
Umbrella-grass - *Fuirena* spp.
33 Rush Fuirena - *Fuirena scirpoidea*
34 Lake-rush - *Fuirena squarrosa*
Umbrella sedges - *Cyperus* spp.
35 Flat sedge - *Cyperus odoratus*
36 Distinct sedge - *Cyperus distinctus*
37 Watergrass - *Luziola fluitans*
38 Water paspalum - *Paspalum repens*
39 Wild-rice - *Zizania aquatica*
40 Yellow-eyed-grasses - *Xyris* spp.

[From CO_2 on page 1]

One of the first researchers to study CO_2 exchange in aquatic plants *in situ* is B.G. Drake, who has studied salt marsh plants since the 1970s. More recently he has collaborated with Curtis, Long, Rozema and Ziska (below) in studies of the effects of elevated CO_2 on salt marsh plant communities.

Another early researcher is S.B. Idso who has studied carbon dioxide effects on azolla, water lily, and water hyacinth. In 1984, he and Kimball found that elevated CO_2 levels reduced the evaporative water loss of water hyacinths. In 1986, he and Clawson concluded that higher CO_2 induces partial stomatal closure, reducing transpirational water loss and significantly increasing foliar temperatures (from 1.5° to 4.5° C). Some believe that transpiration reduction and foliar temperature increases could change global rainfall and temperature patterns, and greatly influence groundwater recharge and surface water hydrology.

In 1987, Idso and his group found that in water hyacinth, carrots, radishes and azolla, enriched CO_2 and a 3° C rise in temperature can increase growth by almost 60% above normal levels. They also found that enhanced CO_2 tends to *reduce* plant growth at relatively cold temperatures of about 18.5° C.

In 1988, Idso enunciated generalities about plant response to atmospheric CO_2 enrichment: under optimum growth conditions (best nutrients, light, temperature) a 300 ppm increase in CO_2 increases plant productivity by about 30%; and increased CO_2 levels enable water-stressed plants to survive drought conditions much better than today's CO_2 levels.

In 1989, Idso et al reported that elevated CO_2 conditions allow azolla plants to grow at higher air temperatures than they are capable of withstanding under current atmospheric CO_2 concentrations. In 1990, they reported that of 25 plant properties of a water lily cultivar, all were "stimulated or enhanced" by a doubling of atmospheric CO_2, including a 49% increase in net photosynthesis, an 18% increase in leaf size and a total biomass enhancement of 270%.

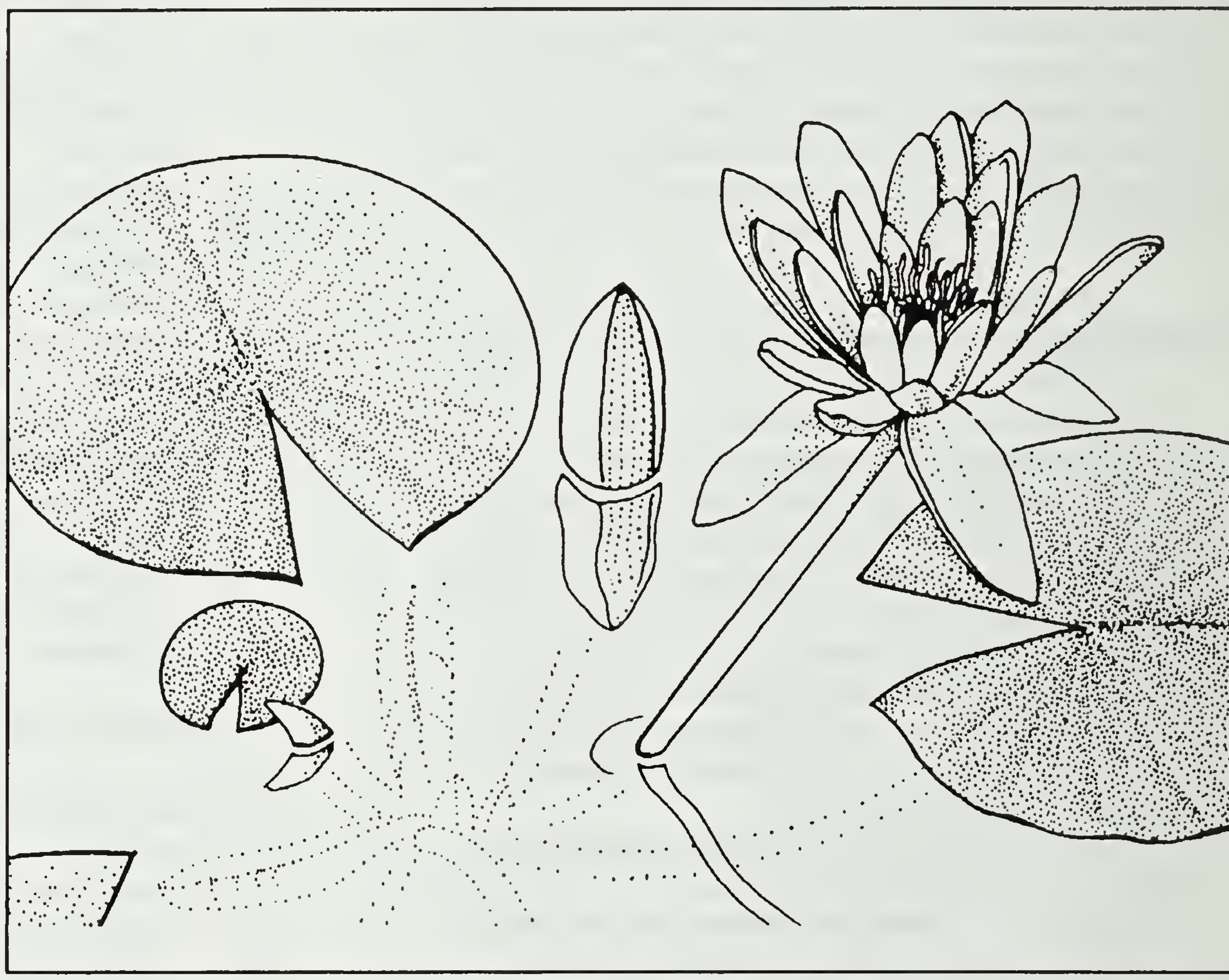
Other researchers have found differences in plant responses to elevated CO_2 depending on plant photosynthetic pathways. Curtis et al (1989) found that C_3 plants such as *Scirpus olneyi* respond to elevated CO_2 concentrations, whereas C_4 plants such as *Spartina patens* were not affected. Curtis wondered if C_3 plants could gain competetive advantage over C_4 species.

Rozema et al (1991) also found that the relative growth rates of C_3 plants were enhanced under elevated CO_2 conditions, but that C_4 species showed no increase. They also found that water use efficiency of all species was increased with elevated CO_2.

Other researchers also study how conditions such as light intensity and temperature affect high CO_2 effects on plants. For example, Guy (1990) found that *Lemna gibba* grown in ponds with higher temperatures and increased CO_2 levels grew much better than those in control ponds with ambient temperature and CO_2. Allen et al (1988) found that high light, temperature and CO_2 increased net photosynthesis of *Azolla pinnata* by as much as 70% above control plants. Allen et al (1990) found that *Nymphaea marliac* also grew much better in increased light intensity, temperature and CO_2.

Researchers have found that sometimes plants become "acclimated" to high CO_2 levels. At the beginning of the studies, the plants may respond positively to high carbon dioxide, but later cease to respond positively. In arctic grass plants, Oechel et al in 1984 found that photosynthesis increased at high CO_2 levels, but the plants acclimated after a year, and after the fourth year there was no detectable difference between elevated and control plot photosynthesis rates.

In a study of water hyacinth grown at *very* high levels of CO_2 (up to 10,000 ppm), Laruigauderie et al found that photosynthesis increased to a maximum at 800 ppm and declined after that; at 2800 ppm, photosynthesis was back down to ambient CO_2 rates. These researchers believe the response depended on the interaction between light intensity and CO_2 levels.



Spencer and Bowes (1986) studied water hyacinth at twice the atmospheric CO_2 level and found the dry weight of ramets grown in enriched CO_2 was increased by 39%. The plants also showed an increased number of leaves and flowers. However the scientists reported the rate of increase was not maintained due to acclimation to CO_2.

Some researchers, such as Dons (1988) hypothesize that CO_2

acclimation results from a starch buildup in the plant which reduces the relative growth rate (RGR). Dons found that duckweed (*Lemna gibba*) rapidly built up starch in elevated CO_2.

Others, such as Poorter et al (1988) believe acclimation to CO_2 may have to do more with the architecture of the plant than with its physiology. In a study of *Plantago major*, they found that the relative growth rate declined as the aerial parts of the plant grew, and concluded that "CO_2 enriched plants are larger and larger plants have a lower RGR due to self-shading."

In contrast, Long and Drake (1991) found no evidence of acclimation and photosynthesis decline in *Scirpus olneyi*, even after three years of growth in elevated (2X) CO_2 concentrations, under light-limited conditions.

And in a long-term study, Ziska (1990) also found no acclimation effect caused by increased CO_2 levels in C_3 plants.

Larigauderie et al (1986) found that the effects of oxygen concentrations (O_2 negatively affects photosynthesis) became less pronounced as CO_2 increased.

For the first time, other researchers are studying the effects of elevated-CO_2-grown plants on the animals that eat them. Lincoln and Couvet (1989) reported that peppermint (*Mentha piperita*) increased in leaf size and weight as CO_2 increased. Allelochemicals increased as well. They also found that caterpillars consumed a greater quantity of elevated CO_2 leaf material. Presumably this was because the nitrogen-to-tissue ratio was lower in high CO_2 plants, so the caterpillars had to eat more to gain the necessary nutrition from them.

Other researchers study *submersed* plants for their responses to increased CO_2 availability in the water. (The increased atmospheric CO_2 will result in increased free CO_2 in water.) Titus' (1990) study shows that *Vallisneria americana* growth was greatly stimulated by free CO_2 enrichment, even in low pH (pH 5) water where the plant would normally show significantly depressed growth. In another study Svedang (1990) shows that *Juncus bulbosus* is invading acidified lakes of Northern Europe because of elevated free CO_2 levels in the water.

Smart (1990) has studied the submersed plants, egeria, hydrilla and Eurasian watermilfoil and found that these plants, even with four times the free CO_2 in the water than controls, did not grow significantly better, probably because of nitrogen limitation.

It is evident that this is only the beginning of the research necessary to answer questions raised by the probable doubling of atmospheric CO_2 by the end of the next century.

- *V.R.*

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[Continued on page 14]

MEETINGS

32ND ANNUAL MEETING, AQUATIC PLANT MANAGEMENT SOCIETY and THE INTERNATIONAL SYMPOSIUM ON THE BIOLOGY AND MANAGEMENT OF AQUATIC PLANTS. July 12-16, 1992, Marriott Hotel, Daytona Beach, Florida.
Topics for this international symposium will include the ecology and photosynthesis of aquatic plants, the use of plant biology to develop better control methods, and environmental impacts of various management options. Post-meeting field trips to the Central Florida and Everglades areas are planned.
For more information, contact Bill Rushing, Secretary-Treasurer, APMS, Inc., PO Box 2695, Washington DC 20013-2695.

INTERNATIONAL SYMPOSIUM ON THE BIOLOGICAL CONTROL AND INTEGRATED MANAGEMENT OF PADDY AND AQUATIC WEEDS IN ASIA. October 12-18, 1992, Tsukuba Science City, Ibaraki, Japan.
The sponsoring agencies are the Food and Fertilizer Technology Center for the Asian and Pacific Region (FFTC/ASPAC) and the National Agriculture Research Center (NARC), MAFF, Japan.
Symposium goals are to identify the significance of paddy and other aquatic weeds in Asian countries; to review the biological control work on these weeds throughout the world; to discuss the development of biological control, and to identify the socio-economic contraints to the adoption of biological control.
For more information, contact Dr. H. Shibayama, National Agriculture Research Center (NARC), MAFF Yatabe, Tsukuba 305, JAPAN.

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Aquatic Plants Go To School

Aquatic plants and their role in the eutrophication process in north central Florida lakes and streams is the topic of a small nine-month grant to produce a curriculum for middle school science teachers and students. Botanist Seth Bigelow and environmental engineer Bill Davis recently received the grant from the Bingham Environmental Education Foundation. An interest in natural history, school children and Florida's unique aquatic plant situation prompted them to devise the program.

Bigelow hopes to encourage student interest in plant biology by bringing plants into the classroom and discussing the reasons for their weed growth potentials. The curriculum will include experiments for students to perform such as rooting certain aquatic plants, hydrilla tuber production and measuring growth rates of duckweed and algae in water of different nutrient, CO_2 and light levels.

Davis is working on the water chemistry portion of the curriculum and will address the topic of phosphorus in Florida lakes. He is developing a simple classroom method to measure phosphorus levels in water and will analyse water samples from local lakes, rivers and springs. Phosphorus additions to water from different detergents will be demonstrated, and experiments will be conducted using aquatic plants to remove nutrients from water and to see if phosphorus diminishes as plant biomass increases.

At the end of the 4-5 week experiment session, students will evaluate and discuss the results. Topics such as eutrophication, aquatic plant growth, wastewater treatment using aquatic plants and others can be addressed based on results of the experiments.

Bigelow and Davis are working with Ms. Elaine Taylor's sixth grade class at Lincoln Middle School in Gainesville. After the new curriculum is evaluated and refined, they hope to distribute it to other middle school teachers in Alachua County. Bigelow and Davis also hope to obtain funding to distribute the new curriculum in other counties.

Bigelow and Davis are doctoral candidates at the University of Florida, Department of Botany and Department of Environmental Engineering, respectively. This independent project is sponsored by Dr. Kimberlyn Williams of the Department of Botany.

WaterWays Education in Public Schools

Wouldn't it be great if children could learn the basics of water cycling and water management while they were still young and interested in things? Well, lucky elementary school students in the Florida panhandle are doing just that, thanks to the **Northwest Florida Water Management District.**

The district has developed *WaterWays*, an environmental education program that provides free teaching materials to teachers and students in all sixteen counties of the district. So well has the program been received that at least two other water management districts are adapting the materials for use in their own counties.

WaterWays "uses a local perspective to give students a broad, general understanding of the need for, and methods of, water management and to lay the groundwork that will enable these future decision-makers to properly manage and protect our water resources."

The program consists of five lessons that range from the broad -- basic facts about water and the water cycle, to the specific -- issues and problems unique to each school district in northwest Florida. Slide/tape presentations give overviews of the contents of each lesson. In addition, the students receive a textbook/workbook that is competently written and well-illustrated. Students get to keep the textbooks, which also describe hands-on activities and experiments suitable for elementary and middle school children. *WaterWays* also provides teachers with a comprehensive guide to help them introduce important terms, provide background information, answer questions, and test students on the material.

To learn more about *WaterWays,* contact: **Office of Public Information, Northwest Florida Water Management District, Route 1, Box 3100, Havana, Florida 32333-9700, (904) 539-5999, ext. 272.**

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AQUAPHYTE

This is the newsletter of the Center for Aquatic Plants and the Aquatic Plant Information Retrieval System (APIRS) of the University of Florida Institute of Food and Agricultural Sciences (IFAS). Support for the information system is provided by the Florida Department of Natural Resources, the U.S. Army Corps of Engineers Waterways Experiment Station Aquatic Plant Control Research Program (APCRP), the St. Johns River Water Management District, and IFAS.

**EDITORS: Victor Ramey
Karen Brown**

AQUAPHYTE is sent to 3,500 U.S. and Canadian managers, researchers and agencies. Comments, announcements, news items and other information relevant to aquatic plant research are solicited.

Inclusion in AQUAPHYTE does not constitute endorsement, nor does exclusion represent criticism, of any item, organization, individual, or institution by the University of Florida.

50% RECYCLED

Not long ago, it was "a new aquarium plant"

In 1945 the editor of *The Aquarium* magazine was asked to identify a luxuriant plant growth in a tank in a sunny store window in Chicago. His friend said somebody called it "Oriental Ludwigia." After a year, it finally flowered and was identified by the University of Pennsylvania as *Hygrophila polysperma.*

The Chicago aquarium dealer thought he had a winner and grew a large stock of the plant for sale. Said the editor in the February 1947 issue of *The Aquarium:* "Now that we can correctly name it and it has had trials under various conditions, he is prepared to broadcast it in a big way. It is our prediction that within two years it will be widely-known and accepted as one of our leading aquarium plants... It now appears to be from India, and to be the only species of the genus that is aquatic -- *Hygrophila polysperma.*"

Forty-five years later, it is now known that the genus *Hygrophila* actually contains about 40 aquatic species. And because *Hygrophila polysperma* is such a prolific exotic, its sale and possession is banned in Florida where it already is becoming a common aquatic weed of the state.

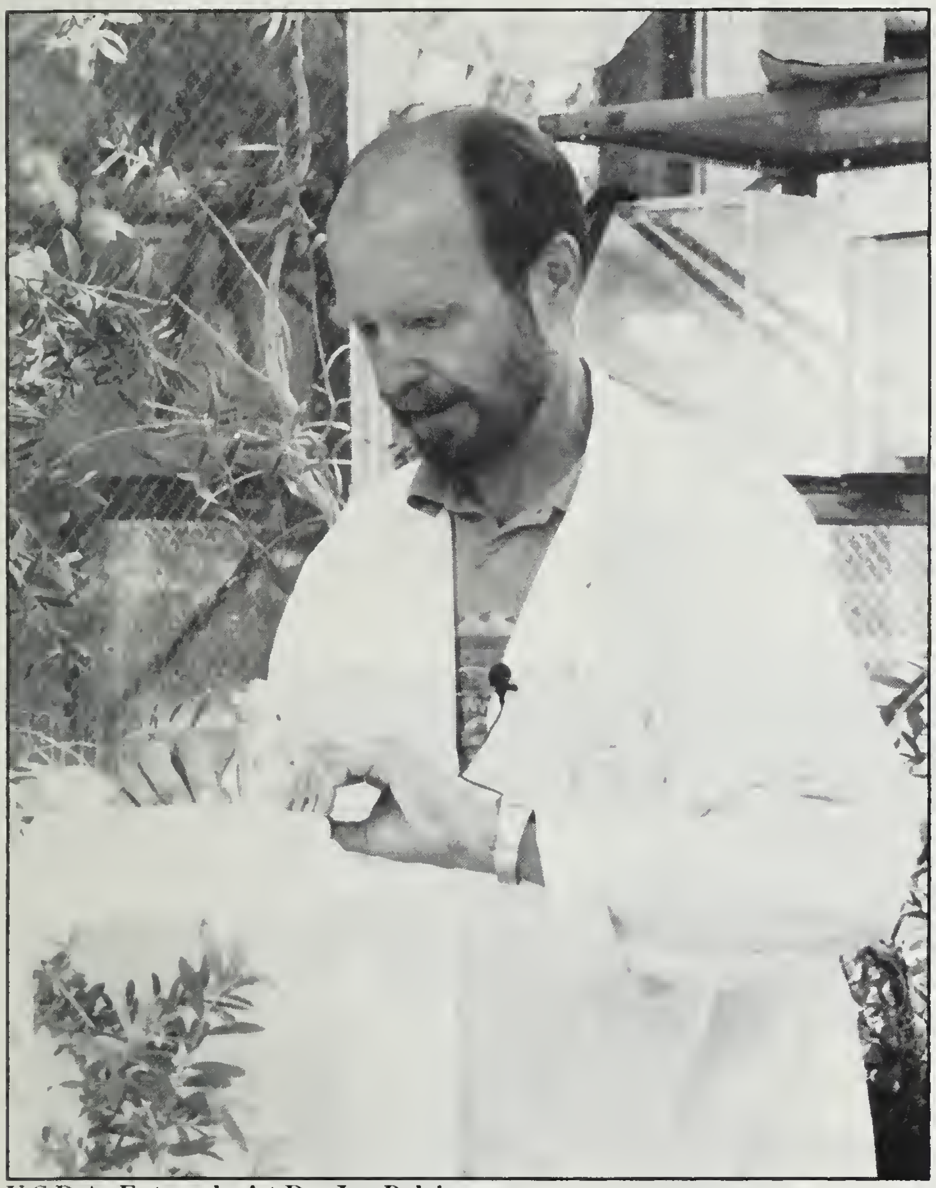
A Q U A P H Y T E

UNIVERSITY OF FLORIDA
CENTER FOR AQUATIC PLANTS
INSTITUTE OF FOOD AND AGRICULTURAL SCIENCES

With Support From
The Florida Department of Natural Resources, Bureau of Aquatic Plant Management
The U.S. Army Corps of Engineers, Waterways Experiment Station,
Aquatic Plant Control Research Program

IFAS
UNIVERSITY OF FLORIDA

Volume 12 Number 2 Fall 1992 GAINESVILLE, FLORIDA ISSN 0893-7702



U.S.D.A. Entomologist Dr. Joe Balciunas

Melaleuca Biocontrol

For the first time, insects for the biological control of the melaleuca tree (*Melaleuca quinquenervia*) are being studied under quarantine in Florida. The two insects are the most promising of the many species that already have been evaluated for host-specificity in melaleuca's home range in Australia. After reproduction, adult feeding and other studies, the insects may be approved for release in South Florida where the exotic melaleuca tree is a quickly spreading menace. Such a release would be history's first attempt at managing trees using biological control agents.

The insects, the defoliating sawfly (*Lophyrotoma zonalis*) and the foliage-feeding weevil (*Oxyops vitiosa*) were delivered to the USDA quarantine facility in Gainesville, Florida.

Are herbivorous fish herbivorous?

by Karol Opuszynski, Ph.D.
Department of Fisheries and Aquatic Sciences
University of Florida, Gainesville

My friend Joe and his wife Pam invited me to a party where I met their friends and neighbors. The food was great, the beer cold, and the mood good. When it was found that I was a fishery biologist, working with grass carp for over 30 years, the conversation turned "fishy". The folks wanted to know more about herbivorous fish and their use for control of aquatic weeds.

I told them it was not quite clear what fish (if any) could be classified as true herbivores and whether the grass carp could be called a herbivorous fish as well. Because this topic had seemingly caught the attention of the party, I decided to write this article hoping the subject might also be interesting to *Aquaphyte*'s readers.

In the main, fish can be classed according to their food habits: herbivorous, omnivorous, or carnivorous. This classification, however, is of limited value because of the complexity of fish food habits. Fish may feed on a striking variety of food including bacteria, unicellular and colonial algae, macrophytes (higher aquatic plants), detritus (dead organic matter mostly of plant origin), and animals from protozoans to vertebrates. Plasticity is a characteristic feature of fish feeding habits.

Most fish are opportunistic, feeding on whatever items are abundant at the time. This is also true of so called "herbivorous fish". There is no evidence that they reject animal food. To the contrary, ingestion of animal food together with plant food is an inevitable consequence of the feeding behaviors of herbivorous fish.

Fish which tear or bite rooted plants (for example, grass carp) ingest together with leaves and plant stems all things living there (often in high densities), including animals such as rotifers, aquatic earthworms, midge larvae, and other water insects. Fish which feed by scraping, whisking or sucking sedimented detritus and algae from the bottom (for example, mullet) ingest small animals living on the bottom as well as bacteria which are abundant in the bottom sediments. This microfauna can be very rich. For example, in one lake, a mat of algae that was scraped from 79 square inches contained 3,500 midge larvae, over

[See Herbivores on Page 12]

DU PONT HALTS WORK ON MARINER HERBICIDE

After more than four years of studies and an undisclosed amount of money spent, E.I. du Pont de Nemours & Company has discontinued efforts to gain registration for the aquatic herbicide Mariner. Mariner contains the same active ingredient, bensulfuron methyl, as another registered herbicide, Londax. Londax is labeled for use on aquatic weeds in rice production.

Mariner was discovered to have a longer life in aquatic environments than Londax does in rice production environments. It also temporarily accumulated in freshwater clams, one of the monitoring organisms. The Environmental Protection Agency required additional studies on non-target organisms, specifically cattle feeding and poultry metabolism trials. These studies would have cost several million dollars more. According to du Pont, the size of the aquatic herbicide market does not warrant the additional money required to label the product for aquatic use.

Researchers had high hopes for Mariner due to its growth regulation activity, especially the inhibition of tuber formation. Dr. Ken Langeland, who has conducted research on Mariner, expressed disappointment at du Pont's decision to discontinue the registration process. He feels strongly that the herbicide would have been a valuable hydrilla management tool. "This demonstrates the need to find avenues to register new products on a need basis rather than a strictly monetary basis. Aquatics is a small market compared to agriculture, which is the major reason for the lack of products labeled for aquatic use." Support for these products might be gained through alternate sources of funding. Potential sources include public agencies since aquatic herbicides primarily are used for public benefit (as opposed to crops which are grown for profit).

WHAT MAKES A QUALITY LAKE?

Good question! Lots of people will give you lots of different answers. In the most recent video production of the Center for Aquatic Plants, limnologist **Dr. Daniel Canfield** answers commonly asked questions and clears up misunderstandings about the "nutrient enrichment" or "eutrophication" of lakes in Florida's unique and varied environment. The program is 24 minutes long.

Produced for the general public, school students and anyone involved in managing aquatic systems, *WHAT MAKES A QUALITY LAKE?* describes the natural and human factors that help determine the trophic state of a lake. Trophic states are defined in terms of water clarity, algae, higher plants and fish.

Other Programs in the Series

- **Florida's Aquatic Plant Story**
- **Istokpoga - Lake of Legends**
- **Calibration - A Field Approach**
- **How to Determine Areas and Amount of Aquatic Herbicide to Use**
- **Floating and Floating-Leaved Plants**
- **Emersed Plants - Part I**
- **Emersed Plants - Part II**
- **Submersed Plants - Part I**
- **Submersed Plants - Part II**
- **Grasses, Sedges and Rushes - Part I**
- **Grasses, Sedges and Rushes - Part II**

Copies may be borrowed from the Information Office (904/392-1799); or they **may be purchased** from IFAS Publications, Building 664, Gainesville, FL 32611 for $15.00 (plus .90 tax for Florida residents), payable to the University of Florida. (Please specify VHS or PAL formats.)

A T T H E C E N T E R

EUROPEAN RESEARCHER VISITS CENTER

Dr. Marija Arsenovic from the Institute for Plant Protection at Novi Sad, in Yugoslavia, spent three months working at the Center this past summer. Working with Dr. William Haller, Dr. Arsenovic performed experiments on time/dose relationships of chelated copper and copper sulfate on hydrilla and Eurasian watermilfoil (*Myriophyllum spicatum*). She also participated in the Aquatic Plant Management Society's 32nd Annual Meeting and International Symposium on the Biology and Management of Aquatic Plants, presenting a paper on "Aquatic Plants in Agricultural Canals in Yugoslavia".

Dr. Arsenovic is from Novi Sad in the province of Vojvodina, a major agricultural area. Vojvodina is the "breadbasket" for provinces of the former Yugoslav federation, supplying one third of the wheat, over one third of the maize, two thirds of the sugar beets and over three quarters of the sunflower crop. Such abundant crop production was made possible by the construction of the Danube-Tisa-Danube system of canals in Vojvodina, a massive thirty year project completed in 1977. The system serves several functions: it irrigates and drains farmlands, supplies water for industrial and household use, serves as a waterway for transport of goods, provides fish breeding habitat and supplies water for fish ponds, and is a potential source of energy. The total length of the canals in the system is 930 kilometers, or 576 miles. It has 30 large sluices, 17 locks and 5 pumping stations, as well as a large concrete dam on the Tisa River.

Dr. Arsenovic is an investigator on the "USA/YU Project on Biological and Chemical Control of Aquatic Weeds" and project leader for "Weed Control on the "Danube-Tisa-Danube" Canal Network System". Flow obstruction in drainage canals is caused by the submersed plants *Ceratophyllum demersum, Myriophyllum spicatum, Potamogeton* spp. and *Ranunculus* spp. *Typha, Phragmites, Carex, Glyceria* and *Juncus* species also cause problems in the canals. A problem with herbicidal control of weeds in the canal system is the potential to affect agricultural crops via irrigation or to harm fish. For this reason, copper-based herbicides are most commonly used for submersed plants. Emergent plants are controlled with glyphosate, imazapyr, and glufosinate-ammonia. Other methods of aquatic weed control used are grass carp and mechanical controls.

Drs. Arsenovic and Haller conducting herbicide time/dose experiments at the Center.

Dr. Arsenovic is an agricultural engineer and assistant professor of Phytopharmacy (Weed Science and Weed Control) on the Faculty of Agriculture at the Institute for Plant Protection. She is also a national representative of several European Weed Research Society (EWRS) working groups, and general secretary of key Yugoslav Weed Research Society projects. She is now on her way back to Novi Sad and a reunion with her husband and two daughters. After a stressful summer of political turmoil in her homeland, we wish her the best.

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Dr. Joseph Joyce, Director

COPPER BIOAVAILABILITY -

Do Copper-Based Herbicides Harm Manatees?

"Our data indicate that manatees accumulate copper in livers in areas where high amounts of copper-based aquatic herbicides are used."- *O'Shea, T.; J. Wildl. Manage. 48(3):741-748, 1984.*

"It appears that the concentrations [of manatee liver-copper from the 1990-92 study] are much lower than those originally reported in the '84 publication by O'Shea."
Unpublished data, S. Wright, Florida Marine Research Institute, Sept. 1992.

The question of bioavailability of copper and other metals was revealed in all its complexity recently at the Workshop on the Bio-Availability and Toxicity of Copper, hosted by the UF IFAS Center for Aquatic Plants.

The workshop was organized in response to recent use-restrictions placed on copper-based herbicides in manatee refugia in Florida. The restrictions were imposed by the Florida Department of Natural Resources for two basic reasons: 1) the fact that copper is a metal and thus does not biodegrade and the concern that copper could potentially be bioavailable in its toxic Cu^{2+} ion form, and 2) in response to an 11-year-old study of manatee livers (O'Shea), in which some manatees were reported to have had liver-copper concentrations that were the highest yet reported in any wild free-ranging mammals.

Workshop Goal

The goal of the copper bioavailability workshop was to "get the facts on the table", and to propose new research to help answer the questions of what happens to copper in Florida's aquatic environments. The workshop was sponsored by the Florida Department of Agriculture and Consumer Services (DACS), the Florida Department of Natural Resources (DNR), the University of Florida Center for Aquatic Plants and the Griffin Corporation.

Water and soil chemists, toxicologists and pathologists, and federal and state regulators presented their perspectives to each other; for most, by the end of the day, scientific certitude had yielded to quiet pondering: are some manatees loaded with toxic or even lethal levels of copper? Does King's Bay, Florida, a major feeding ground for plant-eating manatees, have sediment copper loads that are orders of magnitude higher than natural background levels? What are the fates of the various species of copper ions in aquatic environments, and in aquatic animals? Should copper-based aquatic herbicides use be banned where manatees feed?

Manatees Must Be Protected

The Director of the Division of Resource Management of the Florida Department of Natural Resources, Mr. Jeremy Craft, confirmed that his agency does not want to take a chance with the fate of the manatee; DNR will continue to restrict the use of copper herbicides until studies show that manatees are not harmed by them.

USDI FWS's Charles Facemire agreed that copper aquatic herbicide use should be curtailed in manatee areas, that manatees should be routinely checked for copper poisoning, and that submersed plants should be monitored for their copper content.

Other Regulatory Positions

Rich Budell of DACS said his agency is "concerned" about the issue and wants to help carry out aquatic dissipation or bioavailability studies of copper.

The EPA's copper re-registration manager, Walt Waldrop, said that the copper herbicide industry has already submitted most of the required data for re-registration, with only an avian reproduction study still to be completed. EPA already has "a fairly complete database on copper" and is "not asking for more data" at this time. Waldrop expects copper products to be re-registered at the federal level on schedule by 1995.

Complexed Copper Is Less Bioavailable

USDA's Rufus Chaney argued that because of copper speciation and binding, and the presence of other trace metals in the diet, copper toxicity is difficult to attain, even in copper-sensitive sheep. He cited feeding trials where sheep were fed forage grown in high-copper wastewater sludge. Chaney contended the sheep did not receive lethal or adverse doses of copper because the copper was bound to the organic sludge so tightly that most of it passed directly through the sheep. Dr. Chaney indicated that copper incorporated into plant tissue is not biologically available to animals which ingest them, unless the copper is present in the form of copper salts.

Ron Landis, representing a manufacturers' task force, reported that industry has already spent $1.6 million on copper bioavailability studies, and suggested that the industry had adequately addressed EPA's concerns.

Copper Chemistry in Water and Sediment

Workshop participants were informed about copper fate from chemists Brian McNeal of the University of Florida, William Patrick of Louisiana State University, Bill Landing of Florida State University, and John Mahony of Manhattan College in New York. The chemists described how chemical conditions of the water and sediments determine when copper will exist in its ionic and toxic Cu^{2+} forms, and when copper will combine with naturally occurring compounds in the aquatic system. They showed that ionic copper is rarely found in nature because copper so easily combines with nitrates, sulfates, carbonates and chlorides (as well as with organic compounds) to form new copper compounds. The chemists also explained how copper can be tightly adsorbed to negatively charged clay particles in the water.

The bioavailability of copper depends on many variables such as water pH, how aerobic the ambient conditions are, how much organic carbon is available, how much acid volatile sulfide there is, and so on. For example, in aerobic (oxidized) conditions, complexed copper can shift between different binding sites. On the other hand, in the naturally anaerobic conditions of underwater sediments, copper is tightly bound with other

[See Copper on Page 6]

- Is There A Problem for Manatees?

Photo: U.S. Fish and Wildlife Service, Sirenia Project

These aquatic mammals average about 2,000 lbs. in weight and 10 feet in length. Calves are born and nursed in the water. Adult females average one calf every 3-5 years. Manatees may live to be 40 years old. They are quiet and usually solitary, except when massed in warm water refugia. They are usually slow-moving, but can swim quite rapidly for short bursts. They move by means of their paddlelike flippers and tails.

Manatees are herbivorous and eat large quantities of plants of every description. They are believed to prefer submersed plants but also eat floating plants and even shoreline plants.

Manatees breathe air through their nostrils, holding their breath for one to three minutes as they graze aquatic plants. They have a system to maintain neutral buoyancy as submarines do, so they can easily float underwater while feeding (rather than having to dive and swim as un-weighted humans do). In cold weather, manatees seek relatively warm spring waters. In other months, they may freely migrate among springs, rivers, bays, estuaries and oceans.

Manatees

In 1791, William Bartram described his visit to Florida's "Manate Spring", a "charming nymphaeum, the product of primitive nature, not to be imitated, much less equalled, by the united effort of human power and ingenuity!" At Manate Spring, Bartram saw "amazing and almost incredible troops and bands of fish and other watery inhabitants" quietly moving around and through the "grand fountain", the "astonishing ebullition" of the "lucid sea green" water of Manate Spring.

Unfortunately, Bartram doesn't seem as interested when he describes the "manate or sea cow". Instead, only about four lines describe the manatee skeleton he saw beside Manate Spring. It was the leftovers of the previous winter's grateful Indians, who had eaten "wholesome and pleasant food."

The West Indian manatees (*Trichechus manatus*) are large aquatic herbivorous mammals. Members of the Order Sirenia, manatees populate small areas in Florida and Puerto Rico, South America and Africa. Very similar dugongs live in the western Pacific rim and Indian Ocean.

Research suggests that their numbers were reduced by humans from thousands in the 17th Century to their low numbers today. Other species of "sea cows" have been hunted to extinction, such as Steller's sea cow.

In the United States, manatees are endangered: a one-day statewide (actual) DNR count in 1991 found 1,865 to be the minimum number in Florida. The US Fish and Wildlife Service estimates the number to be 2,000 animals. Manatees are protected under federal acts of 1972 and 1973.

Manatee Mortality

In 1991, 174 manatees died in Florida. Approximately one-third of these deaths were "human related", one-third were unexplained deaths of manatee calves, and another third were adults killed by cold weather, disease and other natural causes, according to the FWS.

Manatee deaths have been caused by poachers; propeller-driven boats; very cold weather, pleurisy and pneumonia; being caught in underwater obstructions such as dam gates and buoy lines; and difficult birthing. Other causes also have been implicated, such as drowning; toxicity from the "red tide"; infection from sting ray barbs; hungry sharks and whales; injury by fish hooks and lures; and starvation from body bloating, a condition possibly caused by excessive fermentation of the manatees' stomach contents. Curiously, there is almost no evidence that alligators regularly attack manatees.

As it has been for several hundred years, the most serious threat to the manatee in Florida today is people. Instead of being hunted for food or ivory (yes, ivory), however, these days they are victims of power boats. Except for individuals that have been conditioned not to, manatees *do* react to fast-moving power boats as they do to other threats: they attempt to escape by diving or by bolting away. However, if surprised while lolling or while grazing on shallow submersed plants, manatees are easily run over.

The cold-sensitive manatees can generally protect themselves from cold water by moving to the relatively warmer waters of springs and power plant thermal discharges. Still, some manatees die annually from cold exposure: 47 died in Florida's 1991 winter.

[From Copper on Page 4]

compounds and is biologically unavailable.

What's Normal for Sirenians?

The question of whether or not some manatees have toxic loads of copper has not been answered. Indeed, no studies at all have been mounted to determine the "normal" liver-copper concentrations of any Sirenians, and copper toxicity symptoms have not yet been observed in any manatees.

In 1984, O'Shea reported that six out of 54 necropsied manatees had liver-copper concentrations ranging from 600-1,200 parts per million (dry weight). 1,200 ppm is the highest liver-copper concentration yet reported in any wild free-ranging mammal. O'Shea concluded that manatees accumulate copper in areas where high amounts of copper-based herbicides are used.

However, high copper, zinc and iron levels have also been reported in populations of other, closely related, Sirenians in Australia. Denton et al (1980) reported that the marine dugongs of Australia had high liver-copper concentrations (to more than 600 ppm) as well as high liver-zinc concentrations (to 4,000 ppm) and high liver-iron concentrations (to 82,000 ppm). Because dugongs are highly mobile ocean-dwelling animals, these researchers concluded that the high metal levels were *not* due to human-related activities.

In a current on-going study of Florida manatee liver-copper loads, DNR's Dr. Scott Wright reported to the copper workshop that the highest manatee liver-copper loads his group has found is 60 ppm Cu (dry weight) from an animal recovered in Duval County. Of the 31 necropsies analyzed so far, only two adult manatees had liver-copper loads above 40 ppm. Three other animals, found in the same area as those studied by O'Shea in 1984 (Citrus County), had liver-copper loads of only 36, 19 and 8 ppm.

Dead or Alive

Instead of analyzing the livers of dead manatees found by chance along Florida's coasts, why not study the tissues of living animals to determine their "normal" liver-copper concentrations, and determine if any animals have high concentrations or suffer from copper toxemia? According to Dr. Wright, the answer is that it is all but impossible to take liver, blubber, kidney or even blood samples from living manatees without imperiling the lives of the endangered subjects.

Copper in Aquatic Plants

The question of where Florida manatees may have gained copper has not been answered. It is known from plant uptake studies that copper concentrations in herbicide-treated plant tissues can be in the thousands of ppm. Since manatees consume huge amounts of aquatic plants, it has been hypothesized that consuming herbicide-treated plants increases their tissue copper concentrations. However, Wright says that manatees are so mobile (individuals may travel hundreds of miles a year) that it would be very difficult to determine the sources of copper intake.

Recommendations

Following the copper workshop, speakers, and DNR and IFAS personnel met to discuss possible research needs relating to the copper issue. They formulated the following question to be answered by research: "Does copper incorporated into the sediments as a result of herbicide use become biologically available as cupric ions and move through the food chain (sediments to plants to animals)?"

Secondary issues which may be considered are: a) what is the effect of copper herbicide use on the productivity of given aquatic systems; b) what is the cupric ion presence in sediments of varying total copper content; and c) what is the copper content of food and feces of captive manatees?

Direct toxicity and loss of habitat as a result of the use of copper-based herbicides would not be the direct issues of concern, rather the effects of sediment incorporated copper would be the focus. Thus we would be dealing with "aged" sediments as they relate to copper and cupric ion presence and past exposure. This would eliminate the issue of the level of direct toxicity testing as it relates to the presence/absence of soil, plants, hardness, etc. in the test vessel.

All participants agreed that the cupric ion and copper salts are toxic at sufficient concentrations, if available in that form. The intent of future research is to evaluate whether or not the presence of copper in the sediments is biologically available as the cupric ion and thus whether there is a relationship between sediment-copper content and content in the associated biota.

Detailed research protocols will be developed and presented to the Florida Department of Agriculture and Consumer Services' Pesticide Review Council for consideration. *V.R.*

O'Shea, T.J.; J.F. Moore; and H.I. Kochman. 1984. *Contaminant concentrations in manatees in Florida.* J. Wildl. Manage. 48(3):741-748

Denton, G.R.W.; H. Marsh, G.E. Heinsohn and C. Burdon-Jones. 1980. *The unusual metal status of the Dugong (Dugong dugon).* Mar. Biol. 57:201-219.

Heavy Metals Hot Spot Discussed

A concentrated metals deposit in King's Bay, Citrus County, Florida, was reported at the copper bioavailability workshop. At a single site (of the 25 sites sampled), several metals registered concentrations that were 1 to 2 orders of magnitude greater than at any other site.

The metal concentrations found at the "hot spot" included chromium (at 123 ppm, dry weight), magnesium (at 2,900 ppm DW), iron (at about 13,000 ppm DW), copper (at 237 ppm DW) and other metals that were higher than the estimated background levels should be, according to Charles Facemire, of the US Fish and Wildlife Service. Aluminum at the hot spot was 17,900 ppm. However, aluminum was assumed to be of natural origin.

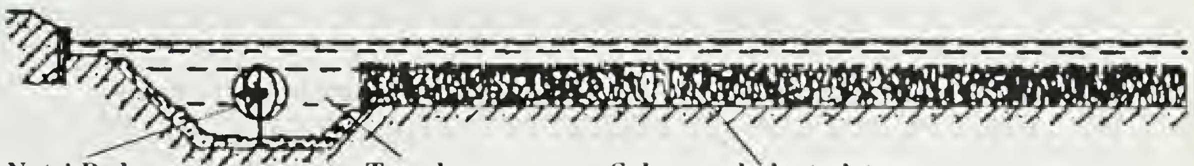
Facemire showed a graphic that depicted concentric lines (isopleths) radiating away from the hot spot, lines that connected sample sites having similar concentrations of the metals. Concentrations became less the further the sample was taken away from the hot spot. There was no explanation for the hot spot other than it was immediately adjacent to a marina.

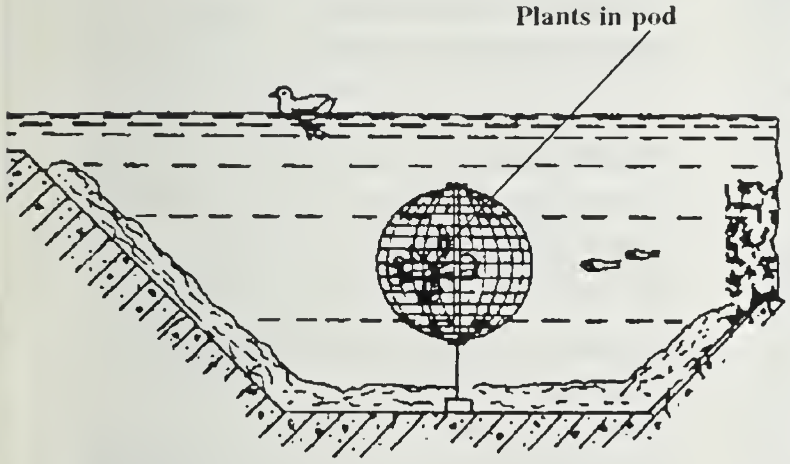
The report was based on one-time 1990 samplings of 25 sites on the approximately 500 acre bay. Samples were taken from the top six inches of sediment. It was noted that it is difficult to draw accurate isopleths from such limited data.

Aquatic Plant Filter System Receives Patent

An artificial water impoundment system which uses aquatic plants to purify nutrient-enriched and polluted water has been awarded US patent number 5,106,504. The inventor is David P. Murray of the Limnion Corporation in Bayview, Idaho.

The patent covers: a relatively deep sedimentation trench (8-20 feet deep), into which polluted water is released; the trench surrounds a shallower plateau (7 feet deep or so) across which water flows through a meadow of rooted "pollution-absorbing" submersed plants; the plants are regularly harvested to remove the bioaccumulated pollutants; and the purified water flows out of the other side of the system.





The system also incorporates another patent of Murray's, namely a porous "submersible pod" in which aquatic plants grow and in the process absorb pollutants from the water. This pod currently is marketed as the "Nutri-Pod". In the system, pods are anchored in the water of the trench just deep enough so that the plants contained in them are able to photosynthesize at the optimum rate. The number of pods used depends on the water nutrient load, the water quality, the time of year, the kind of plants inside the pod, and so on. Plants suggested for the system include species of *Ceratophyllum, Elodea, Myriophyllum, Najas, Vallisneria* and *Potamogeton.*

AQUAPRO 2

MS-DOS version 2.5, $29.95 + $3.00 postage
For this and other programs, contact Aquarium Computer Products, P.O. Box 60, Dundee, MI 48131, (313) 529-3501.

We recently received a copy of **AQUAPRO 2**, a computer program primarily for tank culturists. It was developed by Jay Hemdal, curator of fishes for the Toledo, Ohio, zoo. This is the first computer program of this sort that we have seen. Hemdal is also about to release **MASLEN**, a program to estimate fish mass by using fish length and "body morphololgy".

We asked **University of Florida fisheries extension agent Craig Watson** to review **AQUAPRO 2:**

This software is designed to assist the home aquarist in keeping records on their hobby and to diagnose water quality and disease problems. It includes several modules.

Loading the 3-disk program is straightforward. The program is divided into modules which are accessed from a main menu. Everything is menu driven, and I had no problem going through all the modules without consulting the manual. There is a full-text help menu, but I didn't need to use it.

The **water quality module** is a record keeping section, allowing for water quality parameters to be followed over a period of time, and for reports and graphs to be generated.

The **specimen inventory module** was a simple record keeping module, but also includes cost analysis for individual fish over time.

The **library module** allows for aquarists to index and retrieve article citations. This is a useful module for people who keep all of their magazines for years, but have a hard time remembering which issue had the story on spawning *Synodontis* cats.

The **species compatibility module** was rather interesting, but over simplified. It does include a disclaimer informing the user that deviations from the norm do occur. It asks the user to place two fish whose compatibility are in question in groups of like fish which are listed on the menu. It was accurate in most instances, and erred on the safe side.

The **aquarium analysis module** allows for diagnosis of possible problems, and was fairly accurate in its recommendations on how to correct adverse situations. It even identified errors in data. However, the answers were often the same, regardless of the problem (i.e. "change the water"). Also I didn't always agree with the values for how many fish the aquarium could handle.

The best section in my opinion was the **computer information/calculations/texts module.** Here the user could quickly perform treatment calculations (which are given in a number of values, including teaspoons), conversions, salinity, etc. In my experience with home aquarists, and even professional aquaculturists, this is the area where most people have the hardest time. In the antibiotic section, while it recommended incorporating them in the feed, the program didn't describe how to do this.

The **specimen identification module** was poor. All it does is cross index common name and scientific name, and many of the common names were not the ones I'm familiar with. It didn't ask for descriptions such as color, size, etc., a much more complex program, but one that would actually be of help to many.

The secondary modules allow for more record keeping including necropsy information. I didn't spend much time here.

All said, the program does provide some interesting and useful modules. However, it should not be viewed as the answer to all aquarium problems in its present version.

FROM THE DATABASE

Here is a sampling of the research articles, books and reports which have been entered into the aquatic plant database since March, 1992.

The database has more than 33,000 items. To receive free bibliographies on specific plants and/or subjects, contact APIRS at the address shown on the mail label on page 16.

To obtain articles, contact your nearest state or university library.

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[Herbivores, From Page 1]

10,000 seed shrimps, and over 1,000 copepods, besides a number of other organisms, including mites, mayflies, stoneflies, and caddis larvae. Filter-feeders (for example, gizzard shad and some tilapias) ingest zooplankton together with planktonic algae and microorganisms attached to detritus suspended in the water.

There is a surprising scarcity of information on the quantitative contribution of animal food to the nutrition of herbivorous fish; especially, the importance of very small animals in the diet is essentially unknown. Such microorganisms are the most protein-rich food in nature, and they are easier to digest than plant cells.

Some experts believe that a relative shortage of available protein in the diet is a major factor influencing the abundance of herbivorous fish. Protein is the most important dietary component limiting their growth. Strictly speaking, fish do not need protein *per se*, but require the amino acids which are the product of protein digestion. Because amino acids essential for growth are not synthesized by fish, they must be obtained from the diet. Protein deficiency is not a serious problem in carnivorous fish the diet of which may contain over 80% protein by dry weight. In contrast, herbivorous fish have a low protein diet. In the case of tilapias, this diet may contain even less than 1% protein with most common values being below 15%. Protein content ranged from 1.6 to 7% in macrophytes eaten by marine herbivorous fish. One of the highest protein values (31%) was found in duckweed eaten by grass carp.

Ingestion of animal food by herbivorous fish plays an important role in the alleviation of protein deficiency. This is especially true concerning the fry. As a matter of fact, all herbivorous fish are not herbivorous when young. Once the yolk reserves are exhausted, they depend solely on high-protein animal food to survive and grow. They gradually shift to mixed animal-plant food as they develop and grow.

But animal food is still important in the diet of older fish. This was clearly demonstrated by feeding grass carp with plant and animal food (lettuce and aquatic earthworms) under laboratory conditions. When grass carp were fed only lettuce, they were hardly able to grow. But considerable improvement in growth occurred when the fish were switched to the earthworm diet.

More interesting results were obtained with the mixed diet. When animal food was in excess and plant food restricted, there was a clear reduction (by almost half) in the amount of animal food eaten. The author of these experiments concluded that the grass carp was an omnivorous fish which needed both animal and plant food for good growth and health. Plant food supplies necessary vitamins and carbohydrates used mainly for metabolism, while animal food ensures growth of the fish.

digestion has only been found in two fish species from subtropical Australian waters. Therefore, herbivorous fish must use other mechanisms to break down plant cell walls. These mechanisms include acid hydrolysis and mechanical grinding.

Tilapias possess a unique mechanism for acid lysis of the cell walls. When the fish begins to feed, chloric acid is secreted, making the gastric fluid very acidic (pH values as low as 1.25 - 1.0 have been recorded). Such a strong acid facilitates lysis and digestion of different food materials, including bacteria, algae, and macrophytes. Contrary to fish with

It is argued that the grass carp, and other "herbivorous" fish, do require animal proteins and amino acids for good growth and health. Animal protein is gained by grass carp in the form of many tiny animals that are consumed along with aquatic plants.

Besides the low protein content, plant food is less digestible because plant cell walls are built from cellulose. Cellulose is difficult to break down in enzymatic processes. It still remains unproven whether fish can produce cellulases (the enzymes that break down cellulose). Terrestrial herbivorous vertebrates (for example, ruminants such as cattle) do not produce cellulases. Instead, they rely on intestinal microbes to ferment and digest the plant material. To date, this kind of

highly acid stomachs that chemically break down plant cells, other fish with gizzard-like stomachs (for example, gizzard shad and mullet) and stomachless fish (for example, grass carp) have developed a digestive mechanism that is primarily mechanical. The grinding action of the muscular gizzard stomach is made more effective by the addition of abrasive materials such as sand grains, which are

[See Herbivores on Page 13]

[Herbivores, From Page 12]

ingested together with food. Stomachless fishes do not have jaw teeth; instead, they have well developed "pharyngeal teeth" situated in the throat. These teeth, also called the pharyngeal mill, can cut, tear, and grind the plant material into small fragments.

Once the plant cell walls are broken down and the fish gains access to the cell contents, further food digestion is performed by an apparently conventional set of enzymes. Digestive and assimilative abilities are measured as the food assimilation rate, which is the amount of food assimilated expressed as a percentage of food ingested. This rate is lower in herbivorous fish than in non-herbivorous fish.

The obvious response of herbivorous fish to the relative shortage of protein in the diet and to low food assimilation rates is an increase in the consumption rates. Indeed, herbivorous fish eat more food than non-herbivorous species. For example, the daily ration (in wet weight) of grass carp might exceed their body weight. This high consumption rate along with low assimilation makes the grass carp an attractive choice for management of aquatic weeds. While these fish remove or decrease the density of many unwanted water weeds, they also excrete large quantities of masticated and only partially-digested plant-mass. Grass carp excrement is not only an excellent organic fertilizer, it also is food for many aquatic invertebrates which, in turn, are eaten by many fish species. Therefore, grass carp activity may enhance the growth rate and abundance of valuable game fish.

After all these deliberations, it is time to answer the question asked at the beginning. Yes, I believe that herbivorous fish actually exist. I would define as herbivorous those fish which food constitutes more than 50% plant material by weight or volume, at least in some period of their life. Additional indications of herbivory are morphological and physiological adaptations.

Finally, it is worth mentioning that herbivorous fish, particularly the families Cyprinidae (carps), Cichlidae (tilapias), Mugilidae (mullets), and Chanidae (milkfish) are the most important species in world aquaculture. The silver carp catch alone was 1,359,724 metric tons which ranks this fish first in the total world catch in inland waters.

Among the myriad animals that use aquatic plants is the alligator. At left, Ken Rice and Paul Owen excavate a 'gator nest made of sawgrass (*Cladium* spp.) next to Orange Lake near Gainesville. The eggs were measured, weighed and re-buried in the 3-foot tall mound. The biologists work for the Florida Cooperative Fish and Wildlife Research Unit, a program of of the US Fish and Wildlife Service, the Florida Game and Fresh Water Fish Commission and the University of Florida.

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Water Hyacinths - They're Still Trying To Use Them

In Thailand, work continues apace to find ingenious ways to use the water hyacinth (*Eichhornia crassipes*). Several uses were described by **Dr. Rajanee Virabalin** to the Aquatic Plant Management Society meeting in July. Virabalin is a researcher with the Aquatic Resources Research Institute, Chulalongkorn University, Bangkok. Above left, square meter rafts lined with nets and filled with dried water hyacinth "soil" serve as floating gardens, capable of growing tomatoes, Chinese cabbages and other vegetables from seed. According to the researchers, the vegetables in the floating gardens never need watering or fertilizing. The researchers also found that the leaf protein of water hyacinth is 23%, compared with 4% for water chestnut. The protein fraction contained most essential amino acids, and exceeded the human daily dietary requirements for at least two of them. Other uses of water hyacinth include fashioning dried leaves into baskets and other artifacts, such as the artful chicken, above right.

MEETINGS

20TH ANNUAL CONFERENCE ON WETLANDS RESTORATION AND CREATION. May 13-14, 1993, Sheraton Grand Hotel, Tampa, Florida.

This is a forum for the exchange of research results in the restoration, creation, and management of freshwater and coastal wetlands systems. For information, contact F.J. Webb, Hillsborough Community College, Plant City Campus, 1206 N. Park Road, Plant City, FL 33566, 813-757-2104.

NORTH AMERICAN LAKE MANAGEMENT SOCIETY 12TH ANNUAL INTERNATIONAL SYMPOSIUM. November 2-7, 1992, The Clarion, Cincinnati, Ohio.

The theme for this year's meeting is: *The Year of Clean Water - Past Lessons and Future Challenges.* Topics range from hydropower to phosphorus inactivation to paleoecology to case histories. Poster, video and citizen workshop sessions are planned. For information, contact NALMS, One Progress Blvd., Box 27, Alachua, FL 32615, 904-462-2554.

NALMS: 2ND ANNUAL SOUTHEASTERN LAKES MANAGEMENT CONFERENCE. March 11-13, 1993, Comfort Hotel Rivercentre, Chattanooga, Tennessee.

Organized by NALMS, and co-sponsored by the EPA and the TVA, this workshop is to exchange ideas, improve communication and promote local action on lake and reservoir issues. Send abstracts to Don Anderson, Tennessee Valley Authority, 1101 Market St., HB2C, Chattanooga, TN 37401-2801, or contact NALMS, One Progress Blvd, Box 27, Alachua, Florida 32615-9536, 904-462-2554.

JOINT MEETING - SOCIETY OF WETLAND SCIENTISTS 14TH ANNUAL MEETING, AND THE AMERICAN SOCIETY OF LIMNOLOGY AND OCEANOGRAPHY. May 30-June 3, 1993, University of Alberta, Edmonton, Alberta, CANADA.

The theme for this joint meeting is: *Freshwater, Marine and Wetland Interfaces: Dynamics and Management.* Field trips of peatlands, wetlands, and fresh and saline lakes will be featured. Deadline for abstracts is January 1, 1993. For information, contact Lyndon Lee, L.C. Lee & Associates, Inc., 221 1st Avenue West, Suite 415, Seattle, WA 98119, 206-283-0673.

BOOKS/REPORTS

WETLAND PLANTS IN NEW ZEALAND by P. Johnson; illustrated by P. Brooke. DSIR Field Guide, DSIR Publishing, Wellington. 1989. 319 pp.
(Order from DSIR Land Resources, Private Bag, Christchurch, NEW ZEALAND. US$49.95.)

As the author states in his preface, until this book, "there was no popular treatment to assist students, land managers, or anyone else interested in 'gumboot country' to recognise and name the plants" of New Zealand.

This field guide treats 531 plants of the country's freshwater and saltwater bogs, swamps, estuaries and lakes. They are arranged by groups: algae, ferns and fern allies, conifers, and the two groups of flowering plants, the monocotyledons and dicotyledons. Plant families are in order from the seemingly "primitive" to the seemingly "more advanced."

The line drawings of this book really do look remarkable, and obviously represent much work. Unfortunately, the drawings are reproduced in a small, crowded format that obscures the morphological details, in some cases to the point of oblivion.

PLANTAS INFESTANTES E NOCIVAS (PLANT INFESTATIONS AND WEEDS), Volume 1, by K.G. Kissmann, published by BASF Brasileira S.A. - Industrias Quimicas. 1991. 608 pp. In Portuguese.
(For information, contact K.G. Kissmann, Rua Joao Moura 434, 05412 Sao Paulo, BRASIL. Weed science institutions may order one free copy; for others, the cost per volume is US$100.00.)

This is the first of three volumes. This practical field guide deals with lower plants and monocotyledons. The final two volumes will include the dicotyledon weeds.

Volume 1 includes more than 150 algae, ferns and monocots, many of which are aquatic. Plant treatments include synonymy, common names, distribution, economic importance, biology and morphology.

Treatments are complemented with many exceptional photographs and line drawings. Large text and a spacious format enhance the utility of this extensive work.

AQUACULTURE AND THE ENVIRONMENT by T.V.R. Pillay, Halsted Press, John Wiley & Sons, New York. 1992. 189 pp.
(Order from John Wiley & Sons, Inc., 1 Wiley Drive, Somerset, NJ 08875. $59.95.)

"Aquaculture, which was once considered an environmentally sound practice because of its traditional polyculture and integrated systems of farming based on optimum utilization of farm resources, including farm wastes, is now counted among potential polluters of the aquatic environment and the cause of degradation of wetland areas."

"Efforts are now under way to obtain some of the basic information needed to make appropriate environmental impact assessments of at least some of the culture systems, and to design sound management strategies."

This book includes sections on water quality in aquaculture farms, the nature and extent of aquaculture's impacts on the environment, siting and design considerations, water and waste water use, waste production, escape of exotics, pathogens, effects of birds and mammals on aquaculture farms, safety of aquaculture products, and a final chapter on "environmental management of aquaculture".

A GUIDE TO THE MANAGEMENT OF MIMOSA PIGRA edited by K.L.S. Harley, CSIRO, Canberra, Australia. 1992. 121 pp.
(For information contact CSIRO, Canberra, Australia.)

In the 1800s, the giant sensitive plant (*Mimosa pigra*) was purposely distributed around the world by plant fanciers and others. Since the 1980s, this very prickly plant has come to be regarded as an extremely serious weed of wetlands, especially in Southeast Asia and Australia.

In its native range in Mexico and Venezuela, *M. pigra* grows as a short shrub with limited seed production. Where it has been introduced and has no natural enemies, however, the plant grows prolifically into thick stands more than 12 feet high.

This book contains 13 papers on the biology, biological control, chemical control, "other control" and integrated control of this noxious weed.

VIDEOPHILE

Fate of Pesticides in the Environment

VHS, 1991, 2 tapes, 25 minutes each.

This is a very good introduction to the many processes that determine the environmental fate of pesticides after they are applied. The program is straight-forward, well organized, well paced, and easy to watch and understand. However, it does not present specific examples of pesticides and their fate.

Tape 1 includes an introduction to the kinds of pesticides, and discusses the transfer processes that influence pesticide effectiveness and movement in the environment. Transfer processes include drift, volatilization, adsorption, leaching, erosion and plant/animal uptake.

Tape 2 discusses the degradation processes that affect all pesticides including photochemical, microbial and chemical processes and plant/animal metabolism.

To order, contact Marathon Agricultural and Environmental Consulting, Inc., P.O. Box 6969, Las Cruces, NM 88006-6969. (505) 527-8853. The price is $175.00, including shipping.

A Natural Balance - Restoring Native Habitats

VHS, 1991, 20 minutes.

This video is more than the usual feel-good-about-chemicals-in-the-environment promotional put out by pesticide companies. This well produced program actually takes the trouble to present three real-world problems caused by exotic weeds, and interviews people who obviously don't work for The Company, to show how a chemical product is being used to help the environment.

The convincing examples are about: how the spread of non-native *Spartina* depleted crab and oyster habitats in Washington state, how non-native eucalyptus trees destroyed native species in California, and how non-native giant reed infestations greatly reduced feeding areas for many species of migrating ducks in Delaware Bay.

To order, contact a Monsanto Company representative.

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This is the newsletter of the Center for Aquatic Plants and the Aquatic Plant Information Retrieval System (**APIRS**) of the University of Florida Institute of Food and Agricultural Sciences (IFAS). Support for the information system is provided by the Florida Department of Natural Resources, the U.S. Army Corps of Engineers Waterways Experiment Station Aquatic Plant Control Research Program (APCRP), the St. Johns River Water Management District, and IFAS.

EDITORS: **Victor Ramey**
Karen Brown

AQUAPHYTE is sent to 3,500 U.S. and Canadian managers, researchers and agencies. Comments, announcements, news items and other information relevant to aquatic plant research are solicited.

Inclusion in **AQUAPHYTE** does not constitute endorsement, nor does exclusion represent criticism, of any item, organization, individual, or institution by the University of Florida.

50% RECYCLED

Preserving the Preserves

"In some cases, non-native plants are the single greatest threat to species or communities the preserves were designed to protect... There's no question that a surgeon does grievous damage in the course of removing a cancer, but if he didn't do it, the person might die. In the same way, there are some cases where what the weed would do is worse than what the herbicide might do."

John Randall, The Nature Conservancy "weed czar", explaining the need to sometimes use herbicides to control water hyacinths and other exotic weeds in NC's preserves and parks. In: Alien Invasion by M. Cheater, *Nature Conservancy* magazine, September/October 1992.